The Mars Advanced Radar for Subsurface and Ionospheric Sounding

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Abstract

So far, the planetary explorations have primarily focused on gathering information about the surface of the planets. Recently, due to current speculations of the existence of underground water reservoirs on Mars and possibility of an ocean beneath the Europa's icy surface, there is a growing interest in space-borne radio sounders. Europa orbiter which is currently in the planning stage is considering a radar sounder as one of its science instruments. This paper will focus on the work done on MARSIS (Mars Advanced Radar for Subsurface and Ionospheric Sounding) which is the first of this new generation of radio sounders. MARSIS will be flown on the ESA Mars Express Mission scheduled for launch from Baikonour in June 2003. It will arrive at Mars in early 2004 for a two-year mission.

MARSIS is the result of an international collaboration between NASA, the Italian Space Agency (ASI), and European Space Agency (ESA), is designed to sense planets interior to a depth of up to 5 km. MARSIS' main objective is to search for water if it exists in liquid form under the surface. It will also attempt to map and characterize the subsurface geological structure of Mars, which is hidden under a layer of surface dust. In addition to its subsurface exploration goals, MARSIS will study the ionosphere of Mars providing the most extensive amount of data on Martian ionosphere to date. MARSIS is a challenging project and its design is pushing the envelope in all aspects including transmitter design, a lightweight broadband antenna and on-board processing. MARSIS is designed to operate over a 0.2 MHz to 5.5 MHz frequency range at five distinct bands. The four subsurface sounding bands operate between 1.3 and 5.5 MHz each with a 1 MHz bandwidth. Also, since operation at a low frequency is dictated by the need to penetrate deep below the surface of Mars, MARSIS has to be capable of dealing with distortions that are introduced by the ionosphere. Due to significant limitations in the data transfer rate between the orbiter and Earth, on-board signal processing is required to reduce the data redundancy and maintain a reasonable data rate in order to achieve the goal of global coverage. The on-board data processor consists of a digital processor employing two DSP (Digital Signal Processor) chips. The signal flow

through the processor will be described which allows the basic 5.6 Megabyte per second burst data rate reduced to a level compatible with the spacecraft data handling system of less than 80 kilobits per second.

The MARSIS instrument is designed to operate in an elliptical orbit with a periapsis of 250 kilometers and an apoapsis of 10124 kilometers over the Martian surface. The sounder is to acquire ionospheric data when the orbiter altitude is below 1200 kilometers and subsurface sounding data when the orbiter altitude is below 800 kilometers. For significant penetration of the surface, it is desired to operate at a RF frequency that is as low as possible. The limitations to operating at very low frequencies are the ionosphere of Mars and the physical characteristics of the antenna. The ionosphere of Mars prevents operation at frequencies below 2.5 MHz when the solar zenith angle is less than 80 degrees and at frequencies below 0.5 MHz during nighttime. The antenna length limitation imposed on MARSIS by the Mars Express spacecraft is an antenna dipole with a maximum length of 20 meters. An examination of the surface slope distribution from the MOLA laser altimeter indicates that the surface of Mars has a RMS slope of less than 2 degrees and a RMS height distribution of 4 meters for 90 percent of the surface. For a surface with this roughness, the subsurface returns are expected to be stronger than the surface clutter after the planned Doppler filtering. For the remaining 10 percent of the surface of Mars, the surface roughness has a greater slope distribution and has a higher RMS height. For these rough areas, the return from the surface clutter is expected to dominate over the subsurface returns. In order to separate the surface returns from the subsurface returns, the MARSIS design incorporates a second receive only channel with an antenna that exhibits a null in the nadir direction. The purpose of this second, or surface clutter cancellation channel is to receive mostly off-nadir surface returns. These surface returns can be subtracted from the returns of the main channel reducing the effects of the surface clutter level. The antenna for the surface cancellation channel consists of a 7-meter monopole. The receive channel electronics after the antenna is identical to the subsurface sounding channel.

This presentation will provide an overview of the space-borne low-frequency radar sounding from both the hardware and on board software point of view.